Generation of octave-spanning intense supercontinuum from Yb:doped solid-state lasers in multiple thin plates

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Most few-cycle pulses are formed by compression of an ultrabroadband light source obtained in meter-long hollow-core fiber filled with noble gas [1]. However, the hollow-core fiber scheme requires a careful alignment and is extremely sensitive to the beam-pointing direction, limiting its long-term stability. Recently we reported a novel approach of using a set of plates for continuum generation (MPC, schematic is shown in fig. 1(a)) using 800 nm 28 fs pulses [2]. In this paper, we present a MPC generation scheme for driving with 1030 nm lasers that have pulse duration of as long as 170 fs. We demonstrate a spectrum spanning from 550 nm to 1250 nm, (bandwidth at -20 dB intensity) that is capable of supporting single-cycle pulses while maintaining good output beam quality.

The long laser pulse requires a two-stage approach. Fig. 1(b) shows our cascaded MPC system. A peak intensity of 8.6×10^{12} W/cm^2 is incident onto the first plate in the first stage to initialize spectral broadening. Subsequent plates are inserted by following the procedure described in [3]. After inserting six 200 μm thick quartz plates the output energy of the spectrally-broadened pulse is 575 μJ. The pulse is successfully compressed to 27 fs (8 carrier cycles) by using a Fourier pulse shaper. The pulse energy after the compressor is 195 μJ owing to a low transmission of the spatial light modulator. Eventually, by using custom chirped mirrors, we expect a transmission efficiency of > 50%. We next send the compressed pulses through a second set of quartz plates for further spectral broadening. Fig. 1(c) presents spectra obtained after inserting different number of plates in the second stage. After six 100 μm thick plates, the bandwidth spans from 550 nm to 1250 nm at the -20 dB level. The quality of the output beam is very good, as shown in the inset in Fig. 1(b). The conversion efficiency in the second stage is 55 %, resulting in an output pulse energy of 107.5 μJ. It is clear that adding more plates in this stage introduces a stronger blue shifting of the spectrum than in the first stage. This is because the pulse duration of the input pulses at the second stage is short enough to induce a strong contribution from the self-steepening effect to spectral broadening than in the first stage [3]. The final supercontinuum thus generated can support a pulse duration down to 3 fs (sub-cycle, Fig. 1(d)).

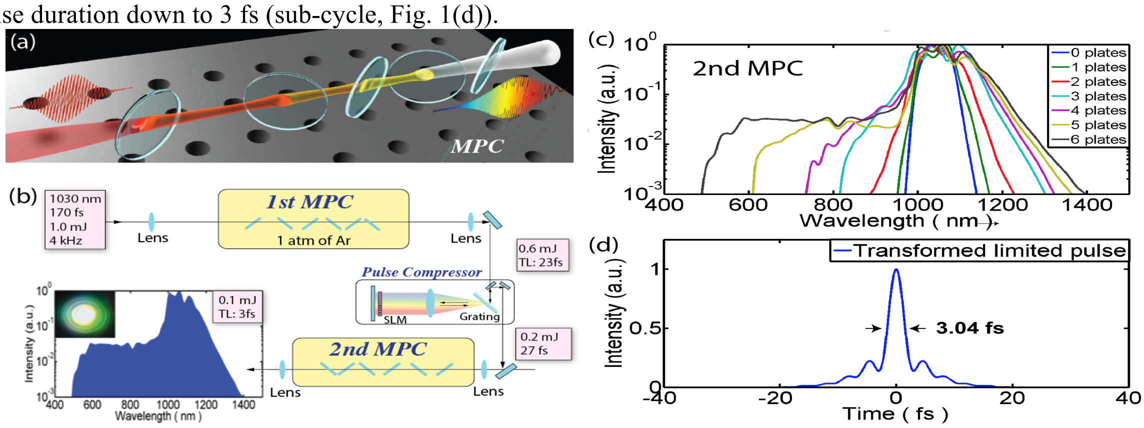

Fig. 1 (a) Schematic of MPC (b)The experimental setup of two-stage MPC, together with the output spectrum and beam profile at the visible part of the spectrum. (c) Spectrum generated with different number of quartz thin plates in the second MPC. The figure is in log scale. (d) The transform-limited pulse shape of output spectrum two MPC system. The TL pulse duration is 3.04 fs (single cycle pulse).

In summary, we have demonstrated two-stage MPC system driven by 1 mJ, 170 fs Yb-based pulses running at a repetition rate of 4 kHz that expands the bandwidth of 1 μm Yb-based laser by > 50 times for the first time, covering more than one octave at -20 dB level while keeping a good output beam quality. After phase compensation, the peak power of these pulses could reach several gigawatts. Such intense, stable diode-pumped single-cycle laser pulses will make isolated attosecond pulses accessible to a broad user community.

References

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